Motion Decoupled FMRI: Event-Related Mapping During Overt Responses

R.M. Birn, P.A. Bandettini, J. Van Kylen, R.W. Cox

Biophysics Research Institute, Medical College of Wisconsin, Milwaukee, Wisconsin, USA

Introduction: The assessment of cortical activity associated with certain tasks, such as overt word production, has been difficult in functional magnetic resonance imaging (FMRI) due to subject motion inherently coupled with the task. This task related motion induces artifactual signal changes which can be misinterpreted as resulting from neuronal activity. Here we present a technique which allows artifactual signal changes arising from brief motion associated with the stimulus to be separated, or decoupled, from the functional blood oxygenation level dependent (BOLD) response.

The basis for this decoupling is that the BOLD response is delayed in time by several seconds due to slow hemodynamics, whereas motion induced signal changes occur in synchrony with the stimulus. In a traditional "block-trial" paradigm, where periods of task are alternated with periods of rest, this brief delay does not significantly affect the temporal overlap between the motion and the BOLD response. By instead using an event related, or "single-trial," paradigm to obtain the average response from a brief stimulus, motion related signal changes occur prior to the BOLD response.

Methods: A series of axial T2* weighted echo-planar images were acquired for tasks of overt word production, jaw clenching, and tongue movement using both a block-trial and a single-trial paradigm. Scans were performed on a Bruker Biospec 3T/60 (TR/TE=1000ms/27.2ms, 10mm slice thickness, 24cm FOV, 64x64). In the block trial paradigm 15-second periods of task (speaking words out loud, repeated jaw clenching, or repeated tongue movement) were interleaved with 15-second rest periods. Images were analyzed by correlating the response with a delayed square wave reference waveform. In the single trial paradigm, the subject performed the task only briefly (spoke one word, one jaw clench, brief tongue movement) every 15 seconds, repeated 20 times. The resulting image epochs were averaged together to produce one 15-second averaged response time course. Data were analyzed by correlating the averaged response with a gamma variate function (1). The effect of motion was reduced by orthogonalizing each pixel time-course with respect to a signal intensity time-course representing the changes due to motion (2)

Results: Functional activation maps obtained with the motion-decoupled single trial technique identified activated regions of the motor cortex for all three tasks, and additional activated regions of the auditory cortex for the overt word production task. In the block-trial paradigm, detection of these regions was obscured by large motion artifacts. Signal intensity time-courses from averaged brief stimulus response indicated large spikes in the first few images corresponding to the motion. In contrast, pixels in functionally active regions had a slower response consistent with the BOLD mechanism.

Conclusion: The motion decoupled single-trial technique reduces motion artifacts by exploiting the characteristics of the hemodynamic response, separating motion and BOLD related signal changes in time. This ability will allow new neuropsychological tests, such as those requiring overt word production, to be assessed with FMRI.

References:

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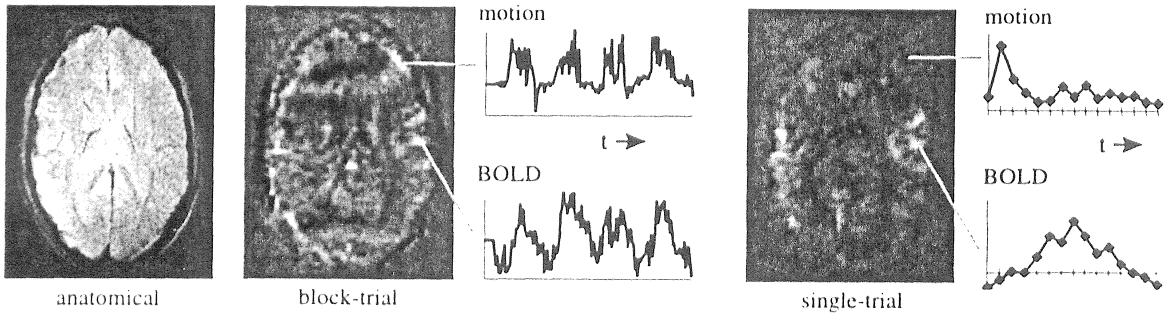

Figure 1: Functional images for the task of overt word production using block-trial and single-trial techniques.